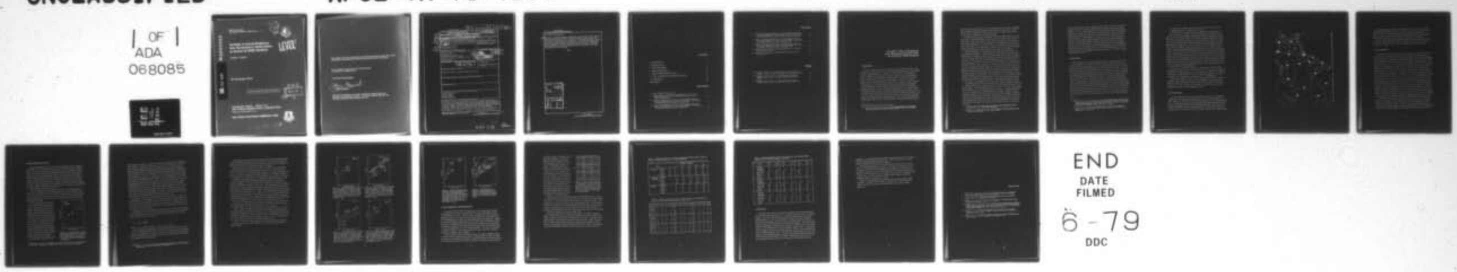
AD-A068 085 AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA F/G 4/2

VARIATION IN GROUND BRIGHTNESS OVER NORTHEASTERN UNITED STATES --ETC(U)

NOV 78 T J KEEGAN

UNCLASSIFIED AFGL-TR-78-0290 NL

1 OF 1
ADA
068085



END
DATE
FILMED
6-79
DDC

ADA068085

DDC FILE COPY

AFGL-TR-78-0290
ENVIRONMENTAL RESEARCH PAPERS, NO. 646

(12) NW

LEVEL II

Variation in Ground Brightness Over Northeastern United States as Sensed by GOES Satellites

THOMAS J. KEEGAN

27 November 1978

Approved for public release; distribution unlimited.

METEOROLOGY DIVISION PROJECT 6670
AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

This report has been reviewed by the ESD Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

John Howard

Chief Scientist

Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.

9 Environmental research papers,

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 AFGL-TR-78-0290, AFGL-ERP-646	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 VARIATION IN GROUND BRIGHTNESS OVER NORTHEASTERN UNITED STATES AS SENSED BY GOES SATELLITES.		5. TYPE OF REPORT & PERIOD COVERED Scientific. Interim.
		6. PERFORMING ORG. REPORT NUMBER ERP No. 646
7. AUTHOR(s) 10 Thomas J. Keegan		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Geophysics Laboratory (LYU) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 [redacted] 667[redacted] 17 Ø8
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory (LYU) Hanscom AFB Massachusetts 01731		12. REPORT DATE 11 27 Nov[redacted]78
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 22p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ground brightness
Clear column
GOES imagery
Cloud forecasting

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The first step in an investigation of the use of satellite imagery data in automated short-range forecasts of clouds and precipitation is to examine the variation in ground brightness under clear-sky conditions. Bedford, Massachusetts, Albany, New York, Pittsburgh, Pennsylvania, and Dulles International Airport, Virginia, were selected as test sites for the period March to December 1977. Data were corrected for error and noise. Navigation was fine-tuned to an accuracy of 1 to 2 pixels. Average, standard deviation, - over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

79 04 26 415

409 578

20. Abstract (Continued)

maximum, minimum and range of brightness were computed over a range of area sizes around each station in order to establish a stable sample size. The statistics stabilized by a 5 × 5 pixel area. Although the number of cases was small, necessitating combining stations, the correlation between brightness and sun angle was high. The slope of the regression curve between these variables was steeper in spring and fall than in summer. Additional data are needed, but it is expected that they will refine rather than revise significantly the present results.

Contents

Illustrations

Illustrations

Tables

Variation in Ground Brightness Over Northeastern United States as Sensed by GOES Satellites

1. INTRODUCTION

In order to meet demands for increasing services with decreasing personnel ceilings, the Air Weather Service (AWS) is making bold changes in its operational format. Among the goals are: automation of observations, centralization of product preparation, and tailoring of selected products for use by the operator with a minimum of interpretation by meteorologists. In many respects, these goals are well on their way towards being achieved. The Air Force Global Weather Central (AFGWC) already has "hands-off" operations, such as computerized flight plans. For support that must be located in the field, the Modular Automated Weather System (MAWS), [1] an advanced observing, communication, display and forecast system, is being developed and tested. A research version of MAWS has successfully demonstrated a complete automated sequence from remote observations to continuously updated forecasts of ceiling and visibility, using an array of wind, temperature and visibility sensors, and a computer algorithm based on climatology and the latest observation. Much of the technology needed by the AWS to meet its goals is already available. Satellite data usage, however,

---

(Received for publication 22 November 1978)

1. Tahnk, W.R., and Lynch, R.H. (1978) The Development of a Fixed Base Automated Weather Sensing and Display System, AFGL-TR-78-0009.

does pose some special problems: First, there is the prosaic matter of managing and processing a tremendous quantity of data generated by the imagery systems; second, there is difficulty in converting this process of imagery information extraction from the subjective to the objective realm.

Commenting on the images transmitted by the early TIROS satellites, the late Arnold Glaser opined that there was a term paper in every picture and a thesis in every orbit. In the ensuing years, many theses and reports have been based on a generalized application of the interpretation of data appearing in just several or even a single image frame. On the one hand, this compliments the skill of these subjective analysts; on the other hand, it implies that most of the data transmitted over the last eighteen years has received no more than cursory attention.

Presently, the globe is covered many times a day by sun-synchronous and geosynchronous satellites. A data explosion has taken place since Glaser made his statement; for example, a point in the south-central United States now appears in over 140 images daily when just the operational satellites of NOAA and DOD are considered. The data volume is further enlarged since Glaser's time by the improved resolution of today's optical systems. The integration of satellite data into automated forecast systems, however, is inhibited not only by the quantity of data but also by reason that satellite imagery does not readily lend itself to objective analysis. Despite all the improvements in satellite sensors and processing embellishments such as animations and electronic displays with superimposed imagery and mapped analysis, interpretations are still made, with few exceptions, from subjective analysis of the imagery. The exceptions are: the use of digital imagery analysis in the AFGWC's 3-D Nephanalysis;[2] some experimental cloud typing by the National Environmental Satellite Service; and techniques developed at AFGL for the purpose of estimating missile erosion caused by hydrometeor impacts.[3]

The development of improved, new and faster computer-compatible techniques for applying satellite data is needed in order to allow the AWS of the future to fulfill its mission. Before these developments can transpire, however, consideration must be given as to how the satellite data are to be used. Current satellite products are not appropriate for current analytical procedures. Satellite sounders generate information on the structure of the thermal field, whereas our dynamic models are driven by the pressure field. Wind vectors, from which the pressure field can be reconstructed, can be inferred from the displacement of clouds between geosynchronous satellite frames. Overlooking the fidelity to which these displacements reflect the wind, one observes that they still do not provide the

2. Coburn, A.R. (1971) Improved Three Dimensional Nephanalysis Model, AFGWC-TM-71-2, Offutt AFB, Nebraska.

3. Bunting, J.T., and Conover, J.H. (1976) The Use of Satellite Data to Map Excessive Cloud Mass, AFCRL-TR-76-0004.

vertical and horizontal continuity required by the models. Until there is a breakthrough, either in our ability to utilize effectively the data provided by satellite sounders, or in our ability to build sensors to collect the appropriate information, satellite data will not be a viable input for dynamic models. But, since satellite imagery does provide information that is not available from any other source, it cannot be ignored. The strength of this imagery lies, first, in the information it provides over data-sparse regions; second, in its spatial continuity and detail; and third, in the frequent updating of data provided by geosynchronous satellite systems. Large scale application is already being made in the 3-D Nephanalysis, as noted earlier. The current need in the 3-D Nephanalysis is a determination of what can be gained by replacing the 3-mile-resolution DMSP data with 1/3-mile-resolution data, and how to handle the addition data volume. This aspect is being investigated at the AFGL.[4, 5]

2. PROGRAM PLAN

The fine spatial and, in geosynchronous satellites, the fine temporal resolution of the imagery are on scales considered ideal for meeting requirements in short-range mesoscale forecasting. The work reported herein is part of a larger program concerned with the development of techniques directed to the use of real-time satellite data in this field of automated, short-range forecasting. In addition to two independent studies being conducted in-house at AFGL, there are contracts with the Space Science and Engineering Center at the University of Wisconsin and also with the Department of Atmospheric Science at Colorado State University, dealing with other aspects of the over-all program. The approach taken in this study is to develop and test statistical methods for specifying and predicting cloud cover and precipitation using geostationary satellite data. The satellite data alone will be used in techniques developed for target-type forecasts and with conventional data in terminal-type forecasts. The ultimate goal is the use of automated procedures (1) to extract required data from the satellite transmission; (2) to process the data with appropriate statistical operators; and (3) to provide the operational decision maker with a forecast expressing one or more of the following probabilities:

---

4. Blackman, E. S., and Pickett, R. M. (1977) Automated Processing of Satellite Imagery Data at Air Force Global Weather Central (AFGWC): Demonstrations of Spectral Analysis, Bolt, Beranek, and Newman, Inc., Final Report Contract No. F19628-76-C-0124, AFGL-TR-77-0080.

5. Fournier, R. F. (1978) An Initial Study of Power Spectra from Satellite Imagery, Scien. Rpt. No. 2, Regis College, Contract No. F19628-77-C-0010, AFGL-TR-77-0295.

1. Occurrence of weather elements critical to local areas or terminals.
2. Specified duration of various weather events.
3. Weather event as a function of various operational threshold values.

Keys to this work, as well as that at the universities, are interactive computer systems with which analysts can manipulate imagery, data, and mapped analyses. A Man-computer Interactive Data Access System (McIDAS) is used at AFGL and the University of Wisconsin. At Colorado State University, an analogous system called All Digital Video Imaging System for Atmospheric Research (ADVISAR) is available. All three sites also have live GOES reception capabilities. At AFGL, McIDAS is used for navigation, that is, solving a transform equation relating satellite and geographic coordinates, and for cloud verification. The University of Wisconsin is using McIDAS to search for predictors by relating features and changes in the imagery with the developments in various circulation fields, including those based on winds derived from the McIDAS analysis of cloud-motion vectors. The approach at Colorado State University is to compare satellite NOWCASTS with the weather forecasts based on NWP methods, that is, Model Output Statistics (MOS), and to develop guidance as to when and where it is best to rely on either the satellite NOWCAST or MOS forecast. Developments on contractual work will be reported separately.

In this report, a systematic approach is taken in which the methodology is the basing of complex decisions on the foundation of more simple ones. Thus, the specification of cloudiness precedes the forecasting of cloudiness, and specification based on a single channel precedes that utilizing two channels. In practice, the sequence of investigation is not expected to be so straightforward.

At the outset, however, the first logical step was taken; that is, to establish the earth surface brightness during clear-sky conditions. It is against these threshold values that cloudiness will be analyzed in later studies. This report covers the results of a preliminary investigation into the hourly, seasonal, and geographic variation in surface brightness of land.

3. DATA PROCESSING

The basic GOES satellite data sample consists of hourly 1-mile-resolution visible and 4-mile-resolution infrared digital data for the northeastern United States (Figure 1). The 1-mile resolution was selected over the 1/2-mile resolution data, for the following reasons: The archiving system used cannot save the infrared data simultaneously with the full resolution visible data. The "truth" data, airways observations, have a temporal resolution of only an hour, which is compatible with the 1-mile spatial and 1-hour temporal resolution of the satellite data.

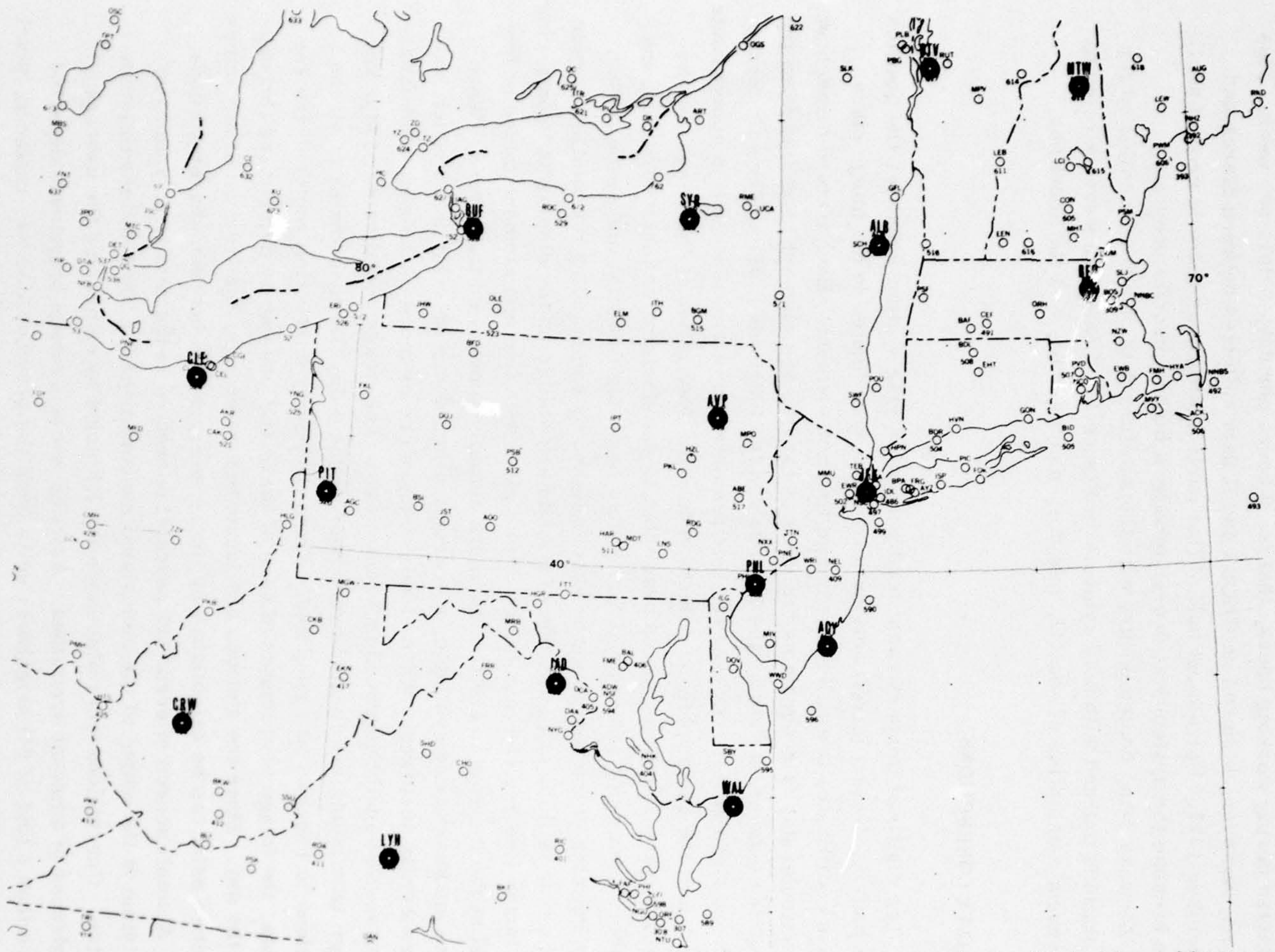


Figure 1. Area of Satellite Imagery Data. Surface reports saved for stations with bold markings

The dependent sample for this pilot study was to consist of one year's data collected during working hours, that is, 8 hours per day, 5 days per week. This report, however, is based on GEOS I and II data collected between March and December 1977. For almost half of that period, afternoon records are not available because the system was pre-empted by a higher priority program.

Airways data, contemporary with the satellite data, have been collected for the stations marked with bold symbols in Figure 1. These data were selected to represent a sampling of coastal, interior, mountainous, and flat locations.

4. DATA CORRECTIONS

The digitized imagery recorded by the archiving system identifies the position of a picture element (pixel) only by its y and x coordinates in the image plane. These coordinates are called the image line and element. Each picture throughout a particular day is programmed to start at the line and element identified from the predicted ephemeris data as the latitude and the longitude of the upper-left corner of the desired sector. Of course, this predicted point provides just an approximate location of the geographic coordinate required. Navigation of the images on the McIDAS system provides an accuracy that is satisfactory for many purposes, but further "tuning-up" is required for studies involving fine time and space scales. This refining of the navigation is accomplished by commanding the McIDAS cursor to the true latitude and longitude of a landmark visible on the display and comparing the image line and element values of this pixel with line and element values of the pixel at the location where the landmark actually appears on the screen. When three landmarks are available, a correction factor can be established which provides 2-mile accuracy. When clouds obscure one or more of the good landmarks, accuracy is usually degraded to 3 to 4 miles. The image coordinates of four key geographic points are located every hour; once a day the coordinates of all the stations in Figure 1 are tabulated. From the hourly correction vector of the key points, the image coordinates of each of these stations can be determined throughout the day. Since the stations are located close enough, the location of any intermediate point can be established by linear interpolation between nearby stations.

A small source of error (±1 percent) corrected in the data is a systematic variation in the output of the four visual sensors used for the 1-mile-resolution sector. Corrections were also made for RF noise by comparing the average brightness of adjacent scan lines. Any line whose average brightness departed more than 5 (out of 64) brightness units from the previous line was replaced, pixel for pixel, by the average brightness in the lines above and below the noisy line.

5. GROUND BRIGHTNESS ANALYSIS

This section describes various tests made on the data in order to establish their stability. The brightness of the ground is in itself an extremely stable parameter for a given solar elevation angle and season. This, of course, does not include the periods in spring and fall when the character of the foliage changes rapidly, or the transitions between bare and snow-covered ground in winter. If the satellite data reflect this natural stability, we will have two very important pieces of information that are basic to any further work: First, there will be a reliable benchmark for measurement of changes in brightness caused by clouds in the first stages of development; second, the data will serve to instill confidence that subtle changes in brightness can be treated as real variations in cloud character, and not manifestations of system noise.

In the following discussion, brightness* values have been multiplied by a factor of 4, in anticipation of future analyses; that is, to make the range of the visible, digitized to 6-bit accuracy, compatible with that of the IR, which is digitized to 8 bits. The statistics presented were computed over a 27×27 pixel box. This is approximately a 25×35 mile area, which is close to the size of a 3-D Nephanalysis grid unit.

The limited amount of completely clear cases available over the period of data collection forced the consideration of widely scattered clouds in the sample. Recognizing that the resulting statistics would be contaminated if other than cases of initial development of widely scattered clouds near or below the sensor resolution were included in the sample, we conducted a preliminary analysis of scattered-cloud statistics. Figure 2 shows the scatter of the average brightness over 729-pixel boxes for days in July 1977 with either clear or low scattered clouds reported at the following four key stations: Bedford, Massachusetts; Albany, New York; Pittsburgh, Pennsylvania; and

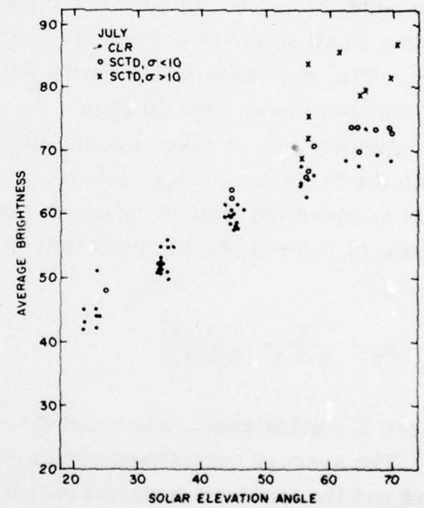


Figure 2. Scatter Diagram of Average Ground Brightness of 9×9 Pixel Boxes Centered at the Four Test Stations During Clear and Scattered Conditions. (See text for definition of brightness)

---

*Visual count values used throughout this report are referred to as brightness for convenience. Brightness is proportional to the square of the visual count.

Dulles International Airport, Virginia. Different symbols are used to differentiate clear conditions, including the presence of a few scattered clouds; low scattered clouds when the standard deviation of the brightness was less than 10; and low scattered clouds when the standard deviations was greater than 10. Although the cases of scattered clouds with small deviations have slightly higher averages than the completely clear cases, the difference is very close to the threshold of instrumental sensitivity. However, it is obvious from the distribution that the scattered cases with large standard deviations belong to a different population. None of the data in Figure 2 were taken after local noon. As a result, the scattered cases with large standard deviations (that is, greater amount of sky covered and/or larger cloud elements) occur only at the higher solar elevation angles, which in this sample represent late morning. Had afternoon data been available, there is little doubt that many cases would have occurred at the lower angles, and that clear cases would have been correspondingly less frequent. The analysis then includes some cases of widely scattered low cumulus clouds. As the data-base increases, these analyses will be repeated using only "severe" clear cases.

In contrast to the minimal effect of widely scattered clouds, haze does have a noticeable effect on the brightness. This will be discussed in a later report. At this point, it can be stated that the effect is characterized by a brighter shade and a very small standard deviation. Not only were the haze cases excluded from the clear data, but cases following the lifting of haze were included only if the visibility improved to at least 10 miles.

Another test of checking stability of the data sample was to compute the albedos from the brightness values (visual counts)[6] and then normalize them for sun angle. This computation includes a sensor calibration. The equation for normalized albedo (A_n) for GOES I in mid-1977 is:

$$A_n = \frac{1}{\cos Z} \left(\frac{C}{234}\right)^2$$

where Z = solar zenith angle and C = number of visual counts.

The average normalized albedo of the ground for a July sample was 8.8 percent and the standard deviation only 0.7 percent. This albedo is at the high end of the range for green forest; it should be characteristic of the suburban residential land use of the Bedford area. The small variance in these ground values reflects the high quality of the data sample.

---

6. Bristor, C. L., Ed. (1975) Central Processing and Analysis of Geostationary Satellite Data, NOAA-TM-NESS-64, Washington, D.C.

The next phase of the analysis investigated the sensitivity of ground brightness to the solar elevation angle as a function of the time of year and station location. Separate statistical relationships based on the average and minimum brightness in the 729-pixel array were computed (see Figures 3 through 7).

Figure 3 illustrates linear regression lines of best fit for the relationship between brightness and solar elevation angle in March 1977. Data from three stations are combined. The fourth station, Albany, had no clear observations that month. For both the minimum and average brightness, correlation coefficients and standard errors of estimate are almost identical; this also holds for the slope.

The April data depicted in Figure 4 suggest that Bedford and Albany belong to different populations than Pittsburgh and Dulles, particularly as regards minimum brightness. This may be the result of differences in foliage. It will be shown here that the brightness and the slope of the regression line both decrease in the warmer months, and thus the differences between the two curves would be more logical if station labels were reversed. More data will have to be examined before this can be explained, if it is, indeed, a real difference and not a result of the small size of the sample. Most probably it is a result of random errors in the small data sample. The same arrangement, only not so pronounced, exists also in the average brightness curves. When the average brightness values of the four stations are combined, the resultant regression is still excellent ($r = 0.90$).

The curves for May, June, and July appear in Figure 5. Except for the slope of the June average brightness curve, there is not much difference among them. The June anomaly may result from the small size of the sample.

August, September, and November had too few cases for analysis. However, in October (Figure 6) and December (Figure 7) the brightness and slope become progressively larger as the leaves turn and then fall. Although the Bedford cases included in the December curve represented snow-covered ground, the values did not differ significantly from those at Dulles, where no snow fell. Nevertheless, the sample is too small to draw any significant conclusions.

Figure 8 summarizes the information concerning the seasonal variation in relationships between average brightness of the ground surface and the solar elevation angle.

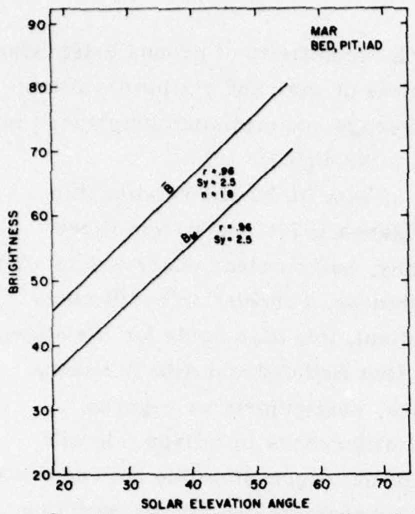


Figure 3. Graph of the Regression Equation for Average ($\overline{B}$) and Minimum (B_m) Ground Brightness vs. Solar Elevation Angle on Clear Days for Stations Indicated on Graph for March 1977. Note that r is the correlation coefficient; S_y, the standard error of estimate; and n, the number of cases

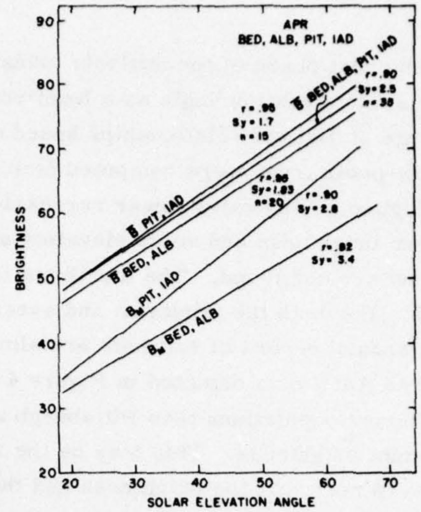


Figure 4. Graph of the Regression Equation for Average ($\overline{B}$) and Minimum (B_m) Ground Brightness vs. Solar Elevation Angle on Clear Days for Stations Indicated on Graph for April 1977. Note that r is the correlation coefficient; S_y, the standard error of estimate; and n, the number of cases.

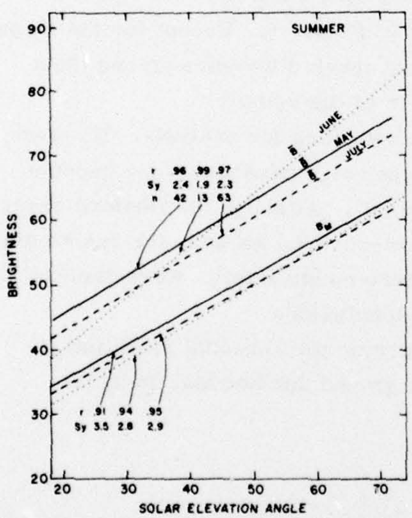


Figure 5. Graph of the Regression Equation for Average ($\overline{B}$) and Minimum (B_m) Ground Brightness vs. Solar Elevation Angle on Clear Days for Stations Indicated on Graph for May, June and July 1977. Note that r is the correlation coefficient; S_y, the standard error of estimate; and n, the number of cases

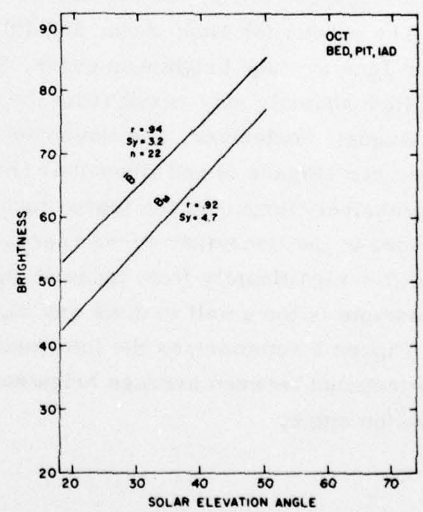


Figure 6. Graph of the Regression Equation for Average ($\overline{B}$) and Minimum (B_m) Ground Brightness vs. Solar Elevation Angle on Clear Days for Stations Indicated on Graph for October 1977. Note that r is the correlation coefficient; S_y, the standard error of estimate; and n, the number of cases.

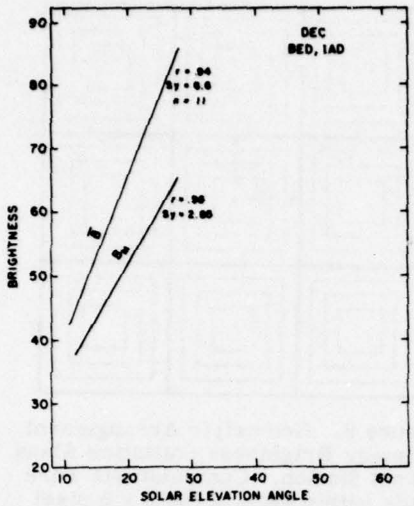


Figure 7. Graph of the Regression Equation for Average ($\bar{B}$) and Minimum (B_m) Ground Brightness vs. Solar Elevation Angle on Clear Days for Stations Indicated on Graph for December 1977. Note that r is the correlation coefficient; S_y, the standard error of estimate; and n, the number of cases

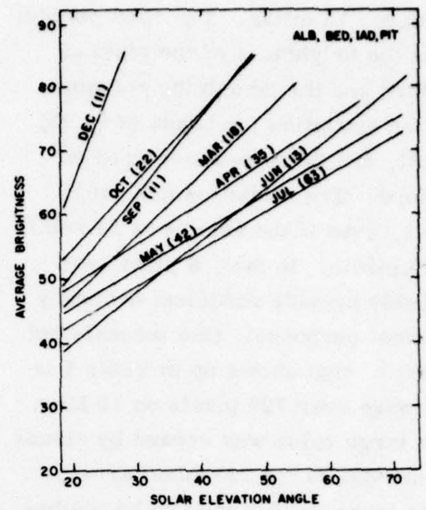


Figure 8. Monthly Variation of Average Ground Brightness as a Function of Solar Elevation Angle. Numbers in parentheses represent number of cases included in each month

6. LOCAL VARIATIONS IN GROUND BRIGHTNESS

A stable relationship exists, within the limits of the data sample, between ground brightness and solar elevation angle over an area significant to current 3-D Nephanalysis practices. The next step is to establish how stable the ground brightness statistics are within this area, since weather on a scale smaller than the 3-D Nephanalysis grid unit is of considerable operational importance. Figure 9 is a schematic diagram of the geometry of the system used to examine the spatial stability of the brightness data. The 729-pixel box surrounding a station used for the previous computations is divided into nine 81-pixel boxes. Each of these boxes is further subdivided into 49-, 25- and 9-pixel squares. For each of these boxes, as outlined in Figure 9, the average, standard deviation, maximum, minimum, and range of brightness were computed.

Table 1 lists the average, standard deviation, and range of brightness values observed by GOES I in the vicinity of Bedford, Massachusetts at 1600Z (1100 EST) on four days in the spring 1977, when the airways observations reported clear skies. On 29 April and 3 May, the visibility was reported as 20 miles, and on the other

two days, 15 miles. The first column gives the brightness of the pixel at Bedford and the remaining columns list the statistics for boxes of 9, 25, 49, 81, and 729 pixels centered on Bedford. The statistics are very stable, even if the sample is as small as 25 pixels. In fact, 9 pixels will probably provide sufficient accuracy for most purposes. One inconsistent statistic that shows up in Table 1 is the range over 729 pixels on 12 May. This large value was caused by clouds at one edge of the 729-pixel array, which were too far away to be visible at Bedford until the next hour and not extensive enough to have any noticeable effect in the average or the standard deviation of the 729-pixel box.

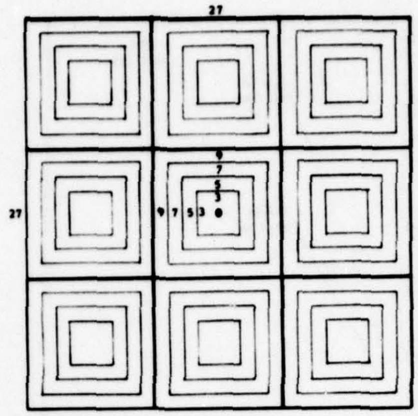


Figure 9. Geometric Arrangement of Image Brightness Statistics About a Test Station. Computations were made within each of the 9×9 pixel boxes for the smaller boxes as indicated at the center. The statistics were also computed for the entire 27×27 pixel area

Table 2 demonstrates the spatial stability of the brightness statistics among the nine 81-pixel boxes within the 729-pixel array for the same set of observations as in Table 1. The lines delineate the nine boxes, as arranged in Figure 9. The stability of the statistics in the areas surrounding Bedford under similar lighting conditions is greater than could be expected of a sensor 23,000 miles away. The only set of deviant values occur in the upper right box on 12 May where the increases in the standard deviation and maximum brightness signal the encroachment of clouds into the Bedford area, as previously noted.

To illustrate the effect of clouds on the statistics, the values for 3 May at 1400Z, when there were scattered clouds at 4,000 ft and 20 miles visibility, are shown in Table 3 along with those for 1600Z when it was clear. The effect of less light is evident in the smaller average and minimum values at 1400Z. The presence of clouds manifests itself in the larger maximum and standard deviation values, and the ragged spatial distribution of the clouds is revealed by the greater variation at 1400Z than at 1600Z of all the statistics from one box to the next.

Table 1. Brightness Statistics in Vicinity of Bedford, Massachusetts at 1600Z as Function of Area on 29 April; 3, 12, and 23 May 1977

Type		Number of Pixels: 1	9	25	49	81	729
Average:	29 April	71	69	69	69	70	70
	3 May	76	72	71	71	71	71
	12 May	75	72	72	72	72	71
	23 May	72	72	71	70	70	70
Standard Deviation:	29 April		1.9	2.7	2.9	2.8	3.2
	3 May		3.2	3.2	3.0	2.9	2.8
	12 May		4.2	3.6	3.0	2.9	3.1
	23 May		1.4	2.0	2.4	2.4	2.6
Range:	29 April		5	13	17	17	21
	3 May		10	11	11	13	18
	12 May		15	15	15	15	50
	23 May		5	8	12	13	18

Table 2. Brightness Statistics Over 9 × 9 Pixel Areas Surrounding Bedford, Massachusetts at 1600Z on Selected Clear Days in 1977

Type	29 April	3 May	12 May	23 May	29 April	3 May	12 May	23 May	29 April	3 May	12 May	23 May
Average	68	70	70	70	70	71	71	71	70	71	72	70
Standard Deviation	2.9	2.8	2.5	2.3	3.7	2.9	2.6	2.7	3.3	2.9	6.1	2.7
Maximum	76	78	77	75	78	79	76	78	78	77	111	75
Minimum	63	64	65	65	57	64	63	63	61	62	61	61
Range	13	14	12	10	21	15	13	15	17	15	50	14
Average	69	70	70	70	70	71	72	70	70	72	72	72
Standard Deviation	2.6	2.7	2.2	2.2	2.8	2.9	2.9	2.4	4.0	2.6	2.7	2.6
Maximum	75	77	75	75	76	77	78	76	78	79	79	79
Minimum	63	64	65	63	59	64	63	63	59	66	65	66
Range	12	13	10	12	17	13	15	13	19	13	14	13
Average	70	72	72	71	70	71	72	70	71	73	72	72
Standard Deviation	2.9	2.3	2.2	2.7	2.7	2.2	2.2	2.4	2.7	2.5	2.1	2.7
Maximum	76	77	77	76	75	77	77	76	77	77	75	78
Minimum	63	65	67	63	63	66	67	65	65	61	65	62
Range	13	12	10	13	12	11	10	11	12	16	10	16

Table 3. Brightness Statistics Over 9 × 9 Pixel Areas Surrounding Bedford, Massachusetts at 1400Z and 1600Z on 3 May 1977

Type	14Z	16Z	14Z	16Z	14Z	16Z
Average	64	70	64	71	66	71
Standard Deviation	5.8	2.8	5.2	2.9	8.5	2.9
Maximum	95	78	89	79	109	77
Minimum	56	64	55	64	54	62
Range	39	14	34	15	55	15
Average	72	70	72	71	67	72
Standard Deviation	14.0	2.7	11.8	2.9	5.7	2.6
Maximum	126	77	108	77	85	79
Minimum	52	64	54	64	56	66
Range	74	13	54	13	29	13
Average	64	72	64	71	64	73
Standard Deviation	5.7	2.3	7.1	2.2	3.0	2.5
Maximum	100	77	103	77	69	77
Minimum	53	65	54	66	50	61
Range	47	12	49	11	19	16

7. CONCLUSIONS

This preliminary analysis of GOES visual imagery data has demonstrated two very important results that impact on the concept of objective analysis of satellite imagery. The first is that the data are of a quality that generates an excellent relationship over a 25 × 35 mile area between average or minimum brightness and solar elevation angle. The relationship is somewhat higher and the scatter of points is less for the average than for the minimum brightness. The slope of this relationship changes as the ground color changes; it is smallest in the warm months months. Some irregularity occurs in the seasonal change of slope. At this point of the investigation, this is not considered serious, since the curves were derived from somewhat contaminated data. The small size of the sample at the time of the analyses necessitated using various combinations of stations and including cases of widely scattered clouds during some months. Despite these liberties, the correlation coefficients were all above 0.90, except for one relationship involving

brightness. As additional data are collected, the regressions will be recomputed using uncontaminated data at individual sites. This will refine but it is not expected to change drastically the current values.

The second result is that even a small sampling of points provides a stable value of the average brightness in a region. This takes on importance for sites where there are frequent local changes in ground brightness, such as near an irregular coastline. An error of several pixels in the navigation could have significant but not illogical effects on the brightness statistics over 729 pixels. Over a smaller area, it should be easier to detect whether changes are caused by changing cloudiness or an incorrect location.

Finally, this investigation has provided a measure of the quality of GOES visual data. It appears to be excellent. Confidence in the data is required in order to progress to the next step — establishing cloud-type and coverage signatures.

References

1. Tahnk, W.R., and Lynch, R.H. (1978) The Development of a Fixed Base Automated Weather Sensing and Display System, AFGL-TR-78-0009.

2. Coburn, A.R. (1971) Improved Three Dimensional Nephanalysis Model, AFGWC-TM-71-2, Offutt AFB, Nebraska.

3. Bunting, J.T., and Conover, J.H. (1976) The Use of Satellite Data to Map Excessive Cloud Mass, AFCRL-TR-76-0004.

4. Blackman, E.S., and Pickett, R.M. (1977) Automated Processing of Satellite Imagery Data at Air Force Global Weather Central (AFGWC): Demonstrations of Spectral Analysis, Bolt, Beranek, and Newman, Inc., Final Report Contract No. F19628-76-C-0124, AFGL-TR-77-0080.

5. Fournier, R.F. (1978) An Initial Study of Power Spectra from Satellite Imagery, Scien. Rpt. No. 2, Regis College, Contract No. F19628-77-C-0010, AFGL-TR-77-0295.

6. Bristor, C.L., Ed. (1975) Central Processing and Analysis of Geostationary Satellite Data, NOAA-TM-NESS-64, Washington, D.C.